VDM Metals

A company of ACERINOX

# VDM® Alloy 40 B

**Material Data Sheet No. 4051** **Revision 01**

July 2021

# VDM® Alloy 40 B

VDM® Alloy 40 B is a cost effective alloy for heating elements with superior properties.

VDM® Alloy 40 B is characterized by:

- Sagging behavior similar to VDM® Alloy HT 60
- Excellent corrosion resistance at high temperatures
- Excellent life time
- Ease of working and processing
- Reduced nickel content compared to VDM® Alloy HT 60

## Designations and standards

| Standard | Material designation |
|---|---|
| DIN EN | 1.4888 - X10NiCrSiLa 38-22 |
| UNS | S35021 |
| ASTM | B344 |

| Product form | ASTM |
|---|---|
| Strip | B344 |
| Wire | B344 |

Table 1 – Designations and standards

# Chemical composition

| | Ni | Cr | Fe | C | Mn | Si | Al | La | S | P | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Min. | 36 | 20 | bal. | | | 1.3 | | 0.03 | | | |
| Max. | 39 | 23 | | 0.12 | 1.0 | 2.2 | 0.5 | 0.20 | 0.03 | 0.03 | 0.5 |

Table 2 – Chemical composition (%)

# Physical properties

| Density | Melting range |
|---|---|
| 7.95 g/cm³<br>0.287 lb/in | 1,350 °C (Solidus) – 1,395 °C (Liquidus)<br>2,462 °F (Solidus) – 2,543 °F (Liquidus) |

| Temperature | | Specific heat | | Thermal conductivity | | Electrical resistivity | Temperature factor | Coefficient of thermal expansion | |
|---|---|---|---|---|---|---|---|---|---|
| °C | °F | $\frac{J}{kg \cdot K}$ | $\frac{Btu}{lb \cdot °F}$ | $\frac{W}{m \cdot K}$ | $\frac{Btu \cdot in}{sq. ft \cdot h \cdot °F}$ | µΩ · cm | $c_t$ = U(T)/U(20 °C) | $\frac{10^{-6}}{K}$ | $\frac{10^{-6}}{°F}$ |
| 20 | 68 | 490 | 0.117 | 12 | 83 | 106 | 1.00 | | |
| 100 | 212 | 500 | 0.120 | 13 | 90 | 109 | 1.03 | | |
| 200 | 392 | 510 | 0.122 | 14 | 97 | 112 | 1.06 | 16.4 | 9.1 |
| 300 | 572 | | | | | 116 | 1.09 | | |
| 400 | 752 | 540 | 0.129 | 18 | 125 | 118 | 1.12 | 16.7 | 9.3 |
| 500 | 932 | | | | | 121 | 1.14 | | |
| 600 | 1112 | 595 | 0.142 | 21 | 146 | 122 | 1.15 | 17.0 | 9.4 |
| 700 | 1292 | | | | | 124 | 1.16 | | |
| 800 | 1472 | 600 | 0.143 | 23 | 160 | 125 | 1.18 | 17.3 | 9.2 |
| 900 | 1652 | | | | | 127 | 1.20 | | |
| 1000 | 1832 | 640 | 0.153 | 26 | 180 | 128 | 1.21 | 17.8 | 9.9 |

Table 3 – Typical physical properties at room and elevated temperatures

# Microstructural properties

VDM® Alloy 40 B has a face-centered-cubic structure.

# Mechanical properties

| Product Form | Yield strength $R_{p\,0.2}$ | | Tensile strength $R_m$ | | Elongation A | Hardness (for information only) |
|---|---|---|---|---|---|---|
| | MPa | ksi | MPa | ksi | % | HV |
| Wire | ≥ 270 | ≥ 39.2 | ≥ 600 | ≥ 87.0 | A100 ≥ 28 *) | – |
| Strip | ≥ 270 | ≥ 39.2 | ≥ 600 | ≥ 87.0 | A50 ≥ 35<br>A5 ≥ 40 | 140 – 200 |

*) Diameter ≥ 0.4 mm

Table 4 – Minimum mechanical properties in the solution-annealed condition for different product forms at room temperature

| Product Form | Yield strength $R_{p\,0.2}$ | | Tensile strength $R_m$ | | Elongation A |
|---|---|---|---|---|---|
| | MPa | ksi | MPa | ksi | % |
| Wire | 350 | 50.8 | 700 | 102 | 32 (A100) |
| Strip | 330 | 47.9 | 650 | 94.3 | 45 (A5) |

Table 5 – Typical mechanical properties at room temperature

| Temperature | | Yield strength $R_{p\,0.2}$ | | Tensile strength $R_m$ | | Elongation A |
|---|---|---|---|---|---|---|
| °C | °F | MPa | ksi | MPa | ksi | % |
| 20 | 68 | 330 | 48 | 689 | 100 | 37 |
| 100 | 212 | 272 | 39 | 611 | 89 | 42 |
| 300 | 572 | 228 | 33 | 595 | 86 | 44 |
| 500 | 932 | 203 | 29 | 582 | 84 | 40 |
| 600 | 1112 | 192 | 28 | 510 | 74 | 48 |
| 700 | 1292 | 170 | 25 | 319 | 46 | 61 |
| 800 | 1472 | 132 | 19 | 156 | 23 | 29 |
| 900 | 1652 | 74 | 11 | 88 | 13 | 22 |
| 1000 | 1832 | 34 | 4.9 | 39 | 5.6 | 23 |

Table 6 – Typical mechanical properties for strip (2 mm thick, grain diameter 37 μm) at elevated temperatures

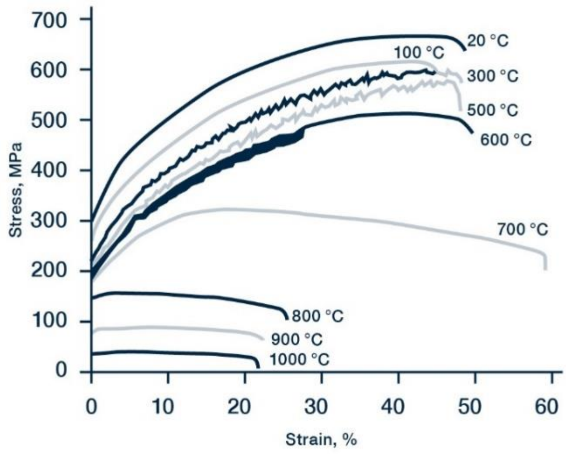


Figure 1 – Stress-Strain curves for VDM® Alloy 40 B at various temperatures

# Sagging test

VDM® Alloy 40 B has superior mechanical properties at high temperatures in comparison to other heating element alloys. During operation at high temperatures, the wire coils must not sag to the extent that they could touch the unit's housing and produce a short circuit. To measure the extent to which the heating coils sag, wire of 1.29 mm diameter is wound into heating coils with an inside diameter of 14 mm and 31 windings. The coils are then inserted into fasteners, separated by 100 mm and electrically heated to a starting temperature of 1,000 °C. Every 30 seconds the current is interrupted for 30 seconds. Every test is done with at least 4 coils from the same production lot. After four hours of operation, the amount to which the coils have sagged in the middle is measured and averaged over the coils of the same test. Figure 2 shows the results for VDM® Alloy HT 60, VDM® Alloy HT 30 and VDM® Alloy 40 B. All wires had the same grain size of 22 µm, because grain size also influences the sagging of the heating element coil. VDM® Alloy HT 60 sagged by about 5.5 mm, VDM® Alloy HT 30 by about 7 mm and an alloy with 40 % nickel melted according to the same principles as VDM® Alloy HT 60 also by about 7 mm. VDM® Alloy 40 B sagged by only 4 mm and therefore showed superior properties.

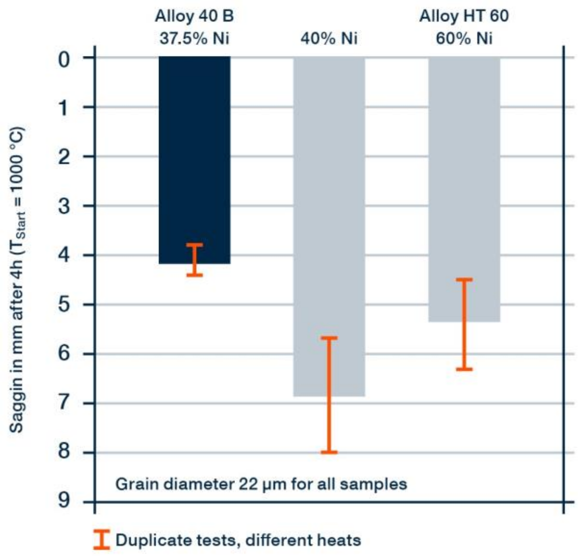


Figure 2 -- Sagging of electrically heated coils of different materials for heating elements. Measured at a starting temperature of 1,000 °C on wires with a diameter of 1.29 mm

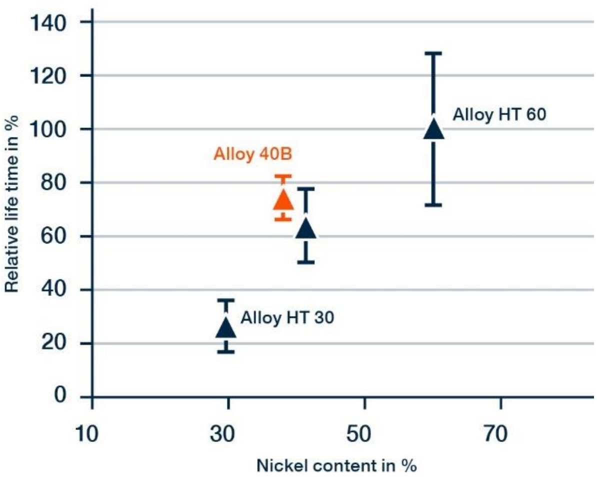


Figure 3 – Relative life time of various alloys for heating elements

# Corrosion resistance

VDM® Alloy 40 B shows excellent oxidation resistance. This is the result of its high chromium and silicon content. The scale is very resistant to spalling because of the addition of about 0.1 % lanthanum.

The life time of alloys for heating elements is tested on wire of 0.40 mm diameter. The wire is heated electrically to a temperature of 1,150 °C., with the current being interrupted for 15 seconds every two minutes. Each test is done with 5 samples from the same production lot, which are averaged. Figure 3 shows the relative life time of various heating element alloys, as a function of nickel content. Life time rises with increasing nickel content. VDM® Alloy 40 B has a life time that is significantly above that of the standard alloys. Its life time is 80 % that of VDM® Alloy HT 60 and more than three times that of VDM® Alloy HT 30.

# Applications

Typical fields of application for VDM® Alloy 40 B are:

- Electric furnaces
- Open heating elements for appliances
- Resistors
- Exhaust systems

# Fabrication and heat treatment

VDM® Alloy 40 B can be easily formed both hot and cold and can also be machined.

## Heating

Production pieces must be clean and free from all kinds of contaminants before and during any heating operation. VDM® Alloy 40 B may become embrittled, if heated in the presence of contaminants such as sulfur, phosphorus, lead and other low-melting-point metals. Sources of such contaminants include marking and temperature-indicating paints and crayons, lubricating grease, fluids and fuels. Fuels must be as low in sulfur as possible.

Natural gas should contain less than 0.1 wt.-% sulfur. Liquid fuels with a sulfur content not exceeding 0.5 wt.-% are suitable. Due to their close control of temperature and lack of contamination, thermal treatments in electric furnaces under vacuum or in an inert gas atmosphere are to be preferred. Treatments in an air atmosphere and, alternatively, in gas-fired furnaces are acceptable though, if contaminants are kept at low levels so that a neutral or slightly oxidizing furnace atmosphere is attained. A furnace atmosphere fluctuating between oxidizing and reducing conditions must be avoided as well as direct flame impingement on the metal.

## Cold forming

For cold working the solution-annealed condition is recommended.

## Heat treatment

Solution annealing can be performed at temperatures typically above 1,150 °C., followed by quenching in water or fast cooling with air or a protective atmosphere. After cold forming a recrystallization heat treatment typically above 1,150 °C., is required.

## Descaling and pickling

Oxides of VDM® Alloy 40 B and discoloration adjacent to welds are more adherent than on standard stainless steels. Grinding with very fine abrasive belts or discs is recommended. Care should be taken to prevent tarnishing. Before pickling, which may be performed in a nitric/hydrofluoric acid mixture, the surface oxide layer must be broken up by abrasive blasting, by carefully performed grinding or by pretreatment in a molten salt bath. Particular attention should be paid to the pickling time and temperature.

| B&S Gauge | Diameter | | Nominal Resistance | | Weight Factor | |
|---|---|---|---|---|---|---|
| | mm | in | Ω/m | Ω/ft | m/kg | ft/lb |
| 14 | 1.628 | 0.0641 | 0.509 | 0.155 | 60.4 | 89.9 |
| 14.5 | 1.536 | 0.0605 | 0.572 | 0.174 | 67.9 | 101.0 |
| 15 | 1.450 | 0.0571 | 0.642 | 0.196 | 76.2 | 113.4 |
| 15.5 | 1.368 | 0.0539 | 0.721 | 0.220 | 85.6 | 127.4 |
| 16 | 1.291 | 0.0508 | 0.810 | 0.247 | 96.1 | 143.0 |
| 16.5 | 1.218 | 0.0480 | 0.910 | 0.277 | 108.0 | 160.7 |
| 17 | 1.150 | 0.0453 | 1.021 | 0.311 | 121.1 | 180.2 |
| 17.5 | 1.085 | 0.0427 | 1.146 | 0.349 | 136.0 | 202.5 |
| 18 | 1.024 | 0.0403 | 1.287 | 0.392 | 152.7 | 227.3 |
| 18.5 | 0.966 | 0.0380 | 1.446 | 0.441 | 171.6 | 255.4 |
| 19 | 0.912 | 0.0359 | 1.623 | 0.495 | 192.6 | 286.6 |
| 19.5 | 0.860 | 0.0339 | 1.825 | 0.556 | 216.5 | 322.3 |
| 20 | 0.812 | 0.0320 | 2.047 | 0.624 | 242.9 | 361.5 |
| 21 | 0.723 | 0.0285 | 2.582 | 0.787 | 306.4 | 455.9 |
| 22 | 0.644 | 0.0254 | 3.254 | 0.992 | 386.2 | 574.7 |
| 23 | 0.573 | 0.0226 | 4.111 | 1.253 | 487.8 | 725.9 |
| 24 | 0.511 | 0.0201 | 5.169 | 1.575 | 613.3 | 912.8 |
| 25 | 0.455 | 0.0179 | 6.519 | 1.987 | 773.6 | 1151.3 |

Table 7 – Information commonly used in the design of heating coils

# Availability

VDM® Alloy 40 B is available in the following standard semi-finished forms:

**Strip**[1)]
Delivery condition: cold rolled, solution annealed and pickeld or bright annealed[2)]

| **Thickness mm (in)** | | **Width**[3)] **mm (in)** | **Coil - inside diameter mm (in)** | | | |
|---|---|---|---|---|---|---|
| 0.02 - ≤ 0.10 | (0.0008 - ≤ 0.004) | 4-200[4)] (0.16-8[4)]) | 300 (12) | 400 (16) | | |
| > 0.10 - ≤ 0.20 | (> 0.004 – ≤ 0.008) | 4-350[4)] (0.16-14[4)]) | 300 (12) | 400 (16) | 500 (20) | |
| > 0.20 - ≤ 0.25 | (> 0.008 – ≤ 0.010) | 4-750 (0.16-14) | | 400 (16) | 500 (20) | 600 (24) |
| > 0.25 - ≤ 0.60 | (> 0.010 – ≤ 0.024) | 6-750 (0.24-30) | | 400 (16) | 500 (20) | 600 (24) |
| > 0.60 - ≤ 1.0 | (> 0.024 – ≤ 0.040) | 8-750 (0.32-30) | | 400 (16) | 500 (20) | 600 (24) |
| > 1.0 - ≤ 2.0 | (> 0.040 – ≤ 0.080) | 15-750 (0.60-30) | | 400 (16) | 500 (20) | 600 (24) |
| > 2.0 - ≤ 3.0[2)]<br>- ≤ 3.0[2)] | (> 0.080 - ≤ 0.120[2)])<br>- ≤ 0.140[2)] | 25-750 (1.00-30) | | 400 (16) | 500 (20) | 600 (24) |

1) Cut-to-length available in lengths from 250 to 4000 mm (10 to 158 in)
2) Maximum thickness: bright annealed -3mm (-0.120 in) cold rolled only – 3.5mm (- 0.140 in)
3) Wider widths subject to special enquiry
4) Wider width up to 730mm (29in) subject to special enquiry

**Wire**
Delivery condition: Cold drawn, bright annealed or annealed and oxidized

| **Round wire (diameter) mm (in)** | **Flat wire (dimension) mm (in)** |
|---|---|
| 0.01 – 12.0 (0.0004 – 0.48) | 0.08 – 1.5mm x 0.4 – 5.5 (0.003 – 0.06 x 0.016 – 0.22) |
| in coils, carriers, standard drums, spools and special spools | |

# Legal notice

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